

## SM Exercises 6

Please note that this set of exercises is due on an unusual date: 03.06.14.

1. (30%) Fill in the table below (only where appropriate):

Particle	Spin (0,L,R,1)	Mass	Color (1,3,8)	Weak Isospin (0,1/2,1)	Electric Charge	Hyper- Charge(Y)
$\nu_{eL}$						
$e_L^-$						
$e_R^-$						
$u_L$						
$d_L$						
$u_R$						
$d_R$						
$W^\pm$						
$Z^0$						
$\gamma$						
$g$						
$W^0$						
$B^0$						
$H$						

2. (10%) Show that for each fermion generation in the Standard Model the following equations are satisfied:

$$\sum_{all} (-1)^n Y = 0, \quad \sum_{all} (-1)^n Y^3 = 0, \quad (1)$$

$$\sum_q (-1)^n Y_q = 0, \quad \sum_{f_L} (-1)^n Y_{f_L} = 0, \quad (2)$$

where  $Y$  is the hypercharge,  $n = 1$  ( $n = 0$ ) for left-handed (right-handed) fermions, and the sum is to be done over the indicated fermion multiplets.

3. (10%) Use dimensional analysis to determine how a generic weak interaction cross section, e.g.  $\sigma(\nu\bar{\nu} \rightarrow e^+e^-)$ , depends on the center of mass energy ( $E$ ), both at low energies,  $E \ll M_W$ , and at high energies,  $E \gg M_W$ .
4. (25%) Draw all the tree-level diagrams that contribute to the following processes in the Standard Model:

a.  $\bar{\nu}_e + e^- \rightarrow \bar{\nu}_e + e^-$

b.  $\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$

c.  $\bar{\nu}_e + \nu_e \rightarrow \bar{\nu}_e + \nu_e$

d.  $e^+ + e^- \rightarrow e^+ + e^-$

e.  $q + q \rightarrow q + q$

f.  $\tau^- \rightarrow 3 \text{ leptons}$

g.  $\mu^- \rightarrow e^- + e^+ + e^-$

5. (25%) Find the term in the Standard Model Lagrangian which is responsible for the coupling  $ZZH$  and write it in terms of  $M_Z$ ,  $e$  and  $\theta_W$ . Find also the coupling  $W^+W^-H$  and write it in terms of  $M_W$ ,  $e$  and  $\theta_W$ .